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Biology of Sea Cucumbers: An Assessment Towards Conservation

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Introduction

Sea cucumbers popularly called holothurians belong to the phylum Echinodermata, which is a distinct phylum in the animal kingdom. Echinoderms are almost exclusively marine, with a variably shaped body which is subdivided into ten areas. They are characterised by the possession of radial symmetry (generally pentamerous), an intradermic skeleton consisting of closely fitted plates, articulated plates, or ossicles, and a peculiar water vascular system of tubes filled with fluid. Holothurians have an orally-aborally elongated body (Fig.1). The body is formed like a short or long cylinder, with the mouth (at the anterior end) encircled by tentacles, and the anus (at the posterior end) often edged by papillae. Holothurians often lay on the substrate with their ventral surface or trivium, formed by the radii. This creeping sole bears the locomotory podia, while on the dorsal surface, or bivium, the podia are often represented by papillae. The mouth is terminal or displaced dorsally, surrounded by a thin buccal membrane, and generally bordered by a circle of tentacles (Fig. 1). Tentacles are buccal podia containing extensions from the water vascular system. Their number varies between 10 and 30, generally being a multiple of five.

There are known to be roughly 1000 species of sea cucumber, and six orders make up the class; aspidochirotida, apodida, molpadiida, elasipodida, dendrochirotida, and dactylochirotida with classification based primarily on tentacle form, calcareous ring form, presence or absence of respiratory trees and tube feet and in some cases ossicle form(s). In the Aspidochirotida all tentacles are of the same size, but in the Dendrochirotida some tentacles are generally smaller. The shape of the tentacles differs among the various orders and is used as a key character. In the Dendrochirotida they are dendritic (branching in an arborescent manner) and can reach a large size when extended. The Aspidochirotida and most Elasipoda have peltate tentacles, each with a central stalk. The Apoda have pinnate tentacles, with a central axis bearing series of digitations. The Molpadida have digitate tentacles, consisting of short projections with small terminal fingers. The body surface is thick, slimy in many species and wears warts, tubercles, or papillae. The anus is often displaced dorsally, encircled by small papillae or anal teeth. The colouration varies between species and sometimes also between individuals of the same species. The creeping sole is often brighter and lighter than the dorsal surface.

Sea cucumbers contribute significantly to the community biomass, being a significant benthic invertebrate community, and their biology and behaviour have more significant effects on physicochemical processes of soft-bottom and reef ecosystems. Commercially exploited sea cucumbers, provide a source of income to millions of coastal fishers worldwide and a source of nutrition to Asian consumers (Purcell et al., 2013). The processed product from sea cucumber is called 'beche-de-mer,' in French, 'iriko' in Japanese, 'haisom' in Chinese and 'trepang' in Indonesian,

and has a very high export value to south-east Asian countries. The sea cucumber is an ideal tonic, higher in protein and lower in fat content and rich in nutrients such as vitamins, amino acids, trace metals and minerals (Bordbar et al., 2011). Sea cucumbers are an integral part of Chinese medicine for the treatment of several diseases like body weakness, impotence, debility of the aged, constipation due to intestinal dryness and frequent urination. Recent research indicated their integral parts in biomedical research, as an important source of several bioactive compounds of anti-angiogenic, anticancer, anticoagulant, anti-hypertension, anti-inflammatory, antimicrobial, antioxidant, antithrombotic, antitumor and wound healing properties. Sea cucumbers have a more significant role in ecosystem functioning by contributing to sediment health via bioturbation; recycling of nutrients; influencing seawater chemistry; bolstering high biodiversity through symbiotic associations; and forming pathways of energy transfer in food chains etc.

Biology of sea cucumbers

Anatomy

The body of an aspidochirote sea cucumber is elongated along the aboral/oral axis. The body wall is thick and well developed. It consists of a non-ciliated epidermis, connective tissue dermis, circular and longitudinal muscles, and a ciliated peritoneum. Muscles control the tentacles, and large longitudinal muscles used in body movement and contraction attach in layers to the calcareous ring forming the majority of the mass of the pharyngeal bulb (Fig 1). The mouth at the centre of the anterior end is surrounded by a thin peristomial membrane (buccal membrane). The body wall is a thick layer of collagenous connective tissue. Most of the thickness of the wall is the connective tissue dermis. There is a thin epidermis outside the dermis. Calcareous ossicles (Fig.1) are present in the outer layer of the dermis of most cucumbers. The shapes of ossicles vary with species and age, and they are essential in taxonomy (Slater and Chen,2015).

The dermis comprises of the central part of the body and concerning commercial exploitation, the thickness, tissue texture, and taste of the dermis are essential elements

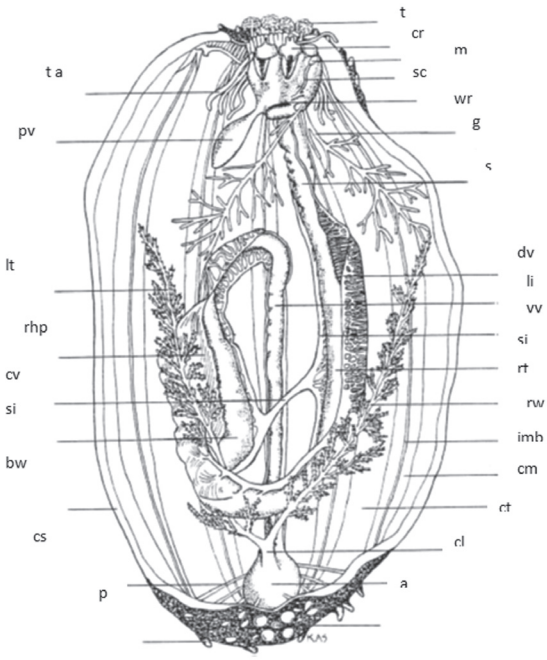

Fig. 1. General sea cucumber anatomy. t, tentacle; cr, calcareous ring; m, madreporite; sc, stone canal; ta, tentacular ampulla; wr, circular water ring; g, gonad; Pv, Polian vesicle; s, Stomach; dv dorsal intestinal haemal vessel; lt, left respiratory tree; li, large intestine; vv, ventral intestinal haemal vessel; rhp, respiratory-haemalplexus; si, Small intestine; cv, cross-ventral intestinal haemal vessel; rt, right respiratory tree; rw, radial water canal; lmb, long muscular band; cm, circular muscle; ct, common respiratory tree trunk; cl, cloaca; cs, Cloacal suspensors; a, anus; p, papilla. Adapted from Hyman, (1955) and Sewell (1987).

influencing their value in the international market. The muscular layer consists of transverse and longitudinal muscles. Its longitudinal muscles are in five strong bands under nervous control. Light stimulus induces muscular contraction causing the body to shrink to a half or as little as one-third its standard size when relaxed.

The calcareous ring is a vital organ. It consists of 10 large ossicles, encircles the anterior end of the gut, supports the ring canals of the water vascular and hemal systems, provides a mechanical base for the buccal podia, and is the site of insertion of the longitudinal body wall muscles. The ring diameter is about one-tenth of body length, which limits the size of food particles, particularly at an earlier juvenile stage.

Reproductive System

In contrast to other echinoderms, the reproductive system of holothurians consists of a single gonad or genital gland. The gonad is attached to the dorsal mesentery through which the gonoduct or genital stolon opening passes, leading to the outside by the gonopore (genital orifice) or a genital papilla. Holothuroids are gonochoric but show no anatomical sexual dimorphism. The gonad composed of either two tufts of tubules, or only one tuft in many species of the family Holothuriidae whose free ends may extend throughout much of the coelom. The gonad becomes enlarged and increasingly branched as maturity is reached before spawning. Following spawning, the gonad tubules are often entirely reabsorbed in temperate species. Observations of tropical species indicate that gonads are present at all times in varying degrees of development (Conand 1993). The sexes are generally separated and show little dimorphism unless in the period of maturing. In most species, the mature gametes are freely released into the seawater. The spawning behaviour, observed in many Aspidochirota species, involves an upright posture of males and females followed by swaying back and forth, while the gametes are being released. The sea cucumber populations are generally present in 1:1 sex ratio. The oocytes of most commercial species of sea cucumbers are usually under 200ìm in diameter, and more or less neutrally buoyant when released in the water column. However, commercial species from temperate regions may possess large yolk buoyant oocytes that can measure up to 1mm in diameter. Reproductive cycles are variable among species, but most tropical species have biannual spawning activity, and fewer species have annual spawning activity. In addition to sexual reproduction, about ten species reproduce asexually by transverse fission by dividing at the middle of the body; both halves re-grow vital organs and form clones of the original individual (Conand,1981; Hyman,1955).

Digestive System

The mouth opens into the pharynx, then to an oesophagus, a stomach, all of which are small structures, and a very long intestine. The intestine consists of three portions, a descending, an ascending, and finally a descending loop which connects to both the rectum and the cloaca opening outwards through the anus. The cloaca opens to the exterior via the anus, which is closed by the anal sphincter. The respiratory trees extend from the cloaca into the coelom. When present, respiratory trees are connected to the cloaca. The oxygenated water enters the body by these water lungs, which are found in all orders except the Apoda. Cuvierian tubules, which are sticky tubules attached to the base of the respiratory trees are present in several species of Aspidochirota,

are generally considered as defensive structures and can be expelled through the cloaca towards the source of irritation.

Respiratory System

The respiratory system consists of tubular structures spring from the anterior part of cloaca near the entrance of the large intestine, which ascends anteriorly into the coelom. The right and left respiratory trees are highly branched evaginations of the wall of the cloaca extending along the body cavity into the perivisceral coelom and are surrounded by coelomic fluid. The trees are anchored to the body wall by delicate connective tissue threads, and the left respiratory tree is intimately associated with the intestine. In addition to the respiratory trees, the entire skin of the sea cucumber has a respiratory function. The skin is capable of sufficiently performing all respiratory function in case of the evisceration of the respiratory trees.

Habitat, growth and longevity

Holothurians are found throughout all oceans, at all latitudes, from the shore down to abyssal plains. They are usually benthic (living on the bottom); some species live on hard substrates, rocks, coral reefs, or concealed under rocks or coral slabs or tucked into crevices, as epizoites on plants or invertebrates; most of the species inhabit soft bottoms, on their surface or in the sediment.

Sea cucumbers are not amenable to conventional tagging methods (Purcell and Kirby, 2006), hence, in general, it is difficult to estimate the growth rate in sea cucumbers (Conand, 1990). However, growth rates in the sea cucumbers have been evaluated by modal progression analysis, genetic fingerprinting, and release and monitoring of juveniles. Purcell and Simutoga,(2008) estimated that *Holothuria scabra* is reaching the size at first maturity (<180 g) in a year but take another couple of years to achieve an acceptable market size. The calculated age at early sexual maturity varies between two and five years for most commercially viable species however significantly faster maturation rates have been reported from commercial aquaculture production (Eriksson et al. 2011; Hamel et al. 2001b; Herrero-Perezrul et al. 1999; Yamana et al. 2010). In general, the longevity of sea cucumbers have been estimated around 10 to 15 years but some species like *Stichopus chloronotus*, it has been estimated around five years (Conand and Sloan, 1989).

Food and feeding

Generally, holothurians exhibited two types of feeding mechanisms. The dendrochirotes are plankton feeders, and they are called suspension feeders, which sweep tiny organisms like plankton and detritus adhering to tentacles through mucous secretion (Hamel and Mercier, 1998). They stretch their tentacles to the fullest extent into the seawater or may sweep them over the surface of the substrates. Minute organisms and detritus adhere to the tentacles through mucus secretion will be engulfed with tentacular contraction. The non-dendrochirotes are deposit feeders, shovel the surrounding substrate into their mouths employing the tentacles and burrowing forms swallow the substrate as they advance through it. They consume detritus, bacteria and diatoms mixed with sediments on the seabed (Conand, 2006).

Life-Cycle

Generally, the aspidochirotes sea cucumbers are broadcast spawners exhibiting seasonal spawning behaviour. Most of the species have biannual spawning, and some have annual spawning behaviour that coincides with the summer months in temperate species. Eggs are generally small and transparent, floating between 100 and 200ìm in most species. Whereas those that are brooded tend to enormous size and yolky content and hence free larval stages are omitted. Cleavage is equal, holoblastic and of the radial types with tiers of cells in line with each other. The pelagic gastrula and early auricularia larvae develop rapidly to feed on microalgae for a period ranging between 12 and 40 days before mature auricularia form the transient doliolaria stage, which exists for less than 24 h before metamorphosis to pentactula and ultimately early juvenile stage.

Conservation of sea cucumbers in India

In India, sea cucumbers have been distributed in Gulf of Mannar, Palk Bay, Lakshadweep and Andaman and Nicobar islands. Mainly the fishery was existed in Gulf of Mannar and Palk Bay and serves as an income source for thousands of fishers in this area. Like in many other Indo-Pacific countries, indiscriminate exploitation and inadequate management measures have caused over-exploitation of sea cucumber resources in the Indian waters, as evidenced from the decrease in export, decreased the size of the specimen fished and absence of certain species from the fishery. The Ministry of Environment, Forests and Climate Change, Government of India implemented a ban in 1982 on export of 'beche-de-mer ' below 75 mm length. The legislation was not much success as the sea cumber fishery was not organised. The Ministry imposed a blanket ban in 2001 which was implemented strictly since 2003, on the fishing and trade of sea cucumbers from Indian waters by listing all holothurians under schedule I of the Indian Wildlife (Protection) Act, 1972. The ban has caused severe impact on the livelihood of poor fishers of Gulf of Mannar and Palk Bay who subsist on the fishery and processing of sea cucumbers from this region. The affected fishermen and traders made repeated representations to the government to lift the ban, citing the negative impact of the prohibition of their livelihood. The ministry entrusted the Zoological Survey of India, to evaluate the effect of the ban and recovery status of sea cucumber stock in the Gulf of Mannar and Palk Bay during 2006 and 2011. The study indicated poor recovery and less improvement of the sea cucumber stock, after implementation of the ban (Venkitaraman, 2006; Venkataraman et al., 2012). The resource surveys and interview surveys conducted by CMFRI under BOBLME indicated that the status of sea cucumber population in the Gulf of Mannar and Palk Bay could be improved if regulatory measures with participatory co-management are followed (BOBLME, 2015). In this context, research on sea cucumber stock restoration and sustainable livelihood based on the culture of commercially important sea cucumber species through hatchery system along with the implementation of suitable fishery regulatory measures have been emphasised in Indian conditions. (Asha et al., 2017).

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